original research report

Standardization of rehabilitation after limb salvage surgery for sarcomas improves patients' outcome

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BACKGROUND AND OBJECTIVE: The purpose of this study is to establish a standardized postoperative rehabilitation protocol following limb salvage surgery (LSS) in patients with primary bone sarcoma in five major anatomical locations: distal femur, proximal tibia, proximal and total femur, humerus and shoulder girdle and pelvic resections.
SETTING AND DESIGN: Retrospective study.
PATIENTS AND METHODS: All LSSs were performed by an orthopedic oncology surgeon, and rehabilitation of all patients was based on a devised standardized rehabilitation protocol. Patient outcomes were measured using the modified Musculoskeletal Tumor Society–International Symposium on the Limb Salvage (MSTS–ISOLS) scoring system.
RESULTS: A total of 59 patients received LSS in the above mentioned locations; endoprostheses were used in 49, bone allograft in five, while no replacements were made in five patients. At a mean follow-up of 24 months, the mean modified MSTS–ISOLS score for all patients was 87% (95% CI; 0.85–0.89). The highest scores were encountered for patients with distal femur replacement: 93% (95% CI; 0.91–0.95). Seven patients had interruption of more than six weeks in their rehabilitation and had a mean score of 71% (95% CI; 0.64–0.82).
CONCLUSION: The proposed rehabilitation protocol is a comprehensive, organized and applicable guideline to be used after performing LSS at the above mentioned anatomical locations. The use of standardized rehabilitation protocol resulted in improved patient functional outcome.

Limb salvage surgery (LSS) is now considered the surgical procedure of choice for local control of malignant bone tumors in more than 90% of patients.[1,2] Numerous studies narrate 67–90% endoprosthetic survival in the lower limbs five years following surgery.[3–9] Furthermore, overall patient survival ranges from 60% to 70%.[10,11] Frieden et al.[12] reported that early mobilization, gait training and adjustment to hospitalization for periodic lengthening of the prosthesis as important seven factors to assure successful rehabilitation. In addition, these studies confirm the efficacy and success of endoprosthetic replacement as a limb-sparing technique for the treatment of osteosarcoma and other malignant bone tumors. However, the most accepted rehabilitation technique for these patients, once the surgery is performed, remains conjectural and is largely untested.[3]

Rehabilitation goals for patients with cancer in the acute care setting may be divided into two major categories: restorative (returning to an independent level of function) and supportive (regaining partial independence in daily activities with improved quality of life). In cases where surgery is performed with curative intent, rehabilitation goals are typically restorative.[13]

Despite widespread agreement on the goals of rehabilitation following limb salvage, the actual rehabilitation guidelines that patients should follow remain undocumented and unpublished.[6] Published reports only address a general description of gait training, active-assisted range of motion and isometric exercises about the joint with no specific details differentiating between different procedures and/or anatomical locations.[12,14] We propose to devise a detailed rehabilitation protocol that addresses different anatomical locations.

MATERIALS AND METHODS

Basic guidelines for rehabilitation following limb salvage surgery have been previously described.[7] These basic narrations were further expanded by the lead author at the King Hussein Cancer Center (KHCC),

Table 1. Rehabilitation after pelvic resection.

After pelvic resections Goal: Healing of abdominopelvic muscles repair under minimal tension. Normal knee and ankle function, and minimal decrease in hip function.		Post-op day 1–3	Post-op day >3	Post-op week 1–6	After 6 weeks
A.Type I Pelvic resection (of the iliac bone)		Keep the ipsilateral limb suspended in flexion (30°) and abduction (30°) using balance traction	A customized abduction brace with a pelvic band (locked in 30° abduction) is applied to the ipsilateral side with weight bearing as tolerated. Use of abductor brace for six weeks	Patient in abductor brace. Mobilize patient's full weight bearing as tolerated Knee and ankle exercises including muscle strengthening and ROM are initiated	Discontinue abductor brace and start active abductor muscles strengthening, mobilization using a cane, until abductor strength is regained
B. Type II Pelvic resection (resection of the acetabulum with endoprosthetic reconstruction) (and Type II/III resections)	Patients with abductor muscles reconstruction	Keep the ipsilateral limb suspended in flexion (30°) and abduction (30°)	A customized abduction brace with a pelvic band (locked in 30° abduction and 0-60° hip flexion), toe touch weight bearing	Mobilize the patient in abduction brace and toe touch weight bearing. Knee and ankle motion exercises encouraged	Discontinue abductor brace and mobilize using crutches or cane. Begin active strengthening exercises of the abductors and flexors
	Patients with acetabular reconstruction prosthesis and abductors are intact (rare)	Keep the ipsilateral limb suspended in flexion (30°) and abduction (30°)	Begin partial weight bearing, use crutches. Ankle and knee exercises encouraged	Begin active hip ROM exercises	Weight bearing as tolerated. Abductors and flexors strengthening
C. Type III Pelvic Resection (resection of the pubic bone)		Bed rest, ankle and knee exercises, bed to chair	Weight bearing as tolerated. Can use crutches as walking aid	Begin active hip ROM and strengthening	N/A

Type I/II/III (complete internal hemipelvectomy): Bed rest in balanced suspension for 3–7 days; Mobilize with toe touch weight bearing using walker; Advance to crutches, weight bearing as tolerated; fit with built-up shoe.

Amman, Jordan and structured into a formalized rehabilitation protocol that individualized the rehabilitation strategy according to the anatomical location, muscle excision and type of reconstruction. The protocol was introduced at the KHCC and fully implemented by July 2006. The detailed protocol addresses all five major anatomical regions frequently encountered in limb salvage surgery (the pelvis, proximal and total femur, distal femur, proximal tibia and proximal humerus and shoulder girdle). For each location, a timeline (ranging from postoperative day 1 to six months) was generated, including specific exercises, restrictions and goals to be achieved. These guidelines are summarized by anatomic site in Tables 1–5.

Detailed instructions were provided in written format to the rehabilitation team while interdisciplinary meetings between the surgeon and the therapist were held every 3–4 weeks to ensure proper implementation of the protocol and discuss ongoing difficulties. A well-trained physical therapist was responsible for applying this protocol under the direct supervision of the surgeon and rehabilitation medicine specialist to ensure that the protocol was rigorously followed and patient progression documented. The study was approved by the institutional ethics committee.

Table 2. Rehabilitation after proximal and total femur replacement.

	Post-op days 1–3	Post-op day 4 to week 6	
After proximal or total femur replacement (bipolar)* Goal: regaining of abductor strength, and prevention of hip dislocation	The limb is suspended in abduction (30°) and flexion (30°). Knee and ankle exercises are encouraged. For total femur, in addition, the knee is immobilized in knee brace.	The patient is mobilized in custom abduction brace (locked in 30° abduction and 0-60° hip flexion), toe touch weight bearing started. Abductor muscles strengthening. For total femur, the knee immobilizer discontinued at two weeks and knee flexion exercises start.	Active hip abduction required before the brace is removed and full weight bearing is allowed (the brace is usually removed after 6–8 weeks)

*PFR with acetabular replacement (THR): Follow total hip precautions for three months (no flexion past 90, no crossing legs, no hip adduction past midline)

Table 3. Rehabilitation after distal femur replacement.

	Post-op day 1–3	Post-op day 3 to week 2	Post-op week 2–6	Post-op >week 6
After distal femur resection (Goal: Knee 0–90°, FWB)	Keep limb elevated, use rigid knee immobilizer (to achieve immobilization and rest only for the first three days), start isometric exercises. Knee flexion NOT allowed.[7] Bed to chair only	Start weight bearing as tolerated for cemented prostheses (always with knee immobilizer). For cementless prostheses partial weight bearing (always with knee immobilizer). Isometric strengthening of knee extensors. Knee flexion NOT allowed	Begin AAROM knee if skin healed. Discontinue knee brace if patient has enough muscle control to do a straight leg raise against gravity. If unable to SLR, then immobilize using the knee immobilizer when ambulating. Full-weight bearing as tolerated. Continue concentration on extensor strengthening. Begin hamstring exercises. Discontinue brace as soon as patient can do SLR.	Start aggressive knee flexion exercises and increase the extensor strength. Consider CPM/dynasplint if flexion <60° MUA contraindicated Examination under anesthesia can be done to assess the cause of limited knee flexion. Surgical release is indicated if knee flexion is < 60 degrees at six months after surgery.

Table 4. Rehabilitation after proximal tibia replacement.[7]

	Post-op day 1–5 (longer period to control swelling)	Post-op day 5 to week 6	Post-op >6 weeks	
After proximal tibia resection Goal: full extension of the limb without any degree of extension lag because lag is detrimental to the ability to ambulate normally	Keep limb elevated. Strictly apply rigid knee immobilizer (or long leg cast). Allow weight bearing as tolerated. Begin AAROM ankle exercise.	No active or passive knee flexion. Keep knee in immobilizer to allow healing of the patellar tendon. Isometric quadriceps strengthening exercises only. No AAROM. Ambulate WBAT.	Begin passive and gentle AAROM for knee flexion. Use of D/C brace while ambulating if the patient can raise the limb against gravity. Target knee flexion range is 0–90°.	We do not aim for a full range of knee flexion at the expense of extension lag. Manipulation under anesthesia contraindicated.

Table 5. Rehabilitation after proximal humerus replacement and shoulder girdle resections.

	Post-op days 1–10	Post-op >day 10	Post-op >6 weeks
After – Proximal humerus (for both Intra and Extra articular resection). – Tikhoff-Linberg procedure – Scapular prosthesis replacement.Goal: Normal hand, wrist and elbow function. Shoulder joint stability. Limitations: Usually above shoulder hand activities are lost.	Keep arm in sling (or immobilizer). Start hand exercises. AAROM of elbow. Avoid elbow full extension to protect flexor muscles (corcaobrachialis, short head of biceps) attachments. Occupational therapy	Take off arm sling for gentle Codman I/II shoulder exercises. Active hand/elbow strengthening. Start elbow full extension exercise after week 4. For scapular replacement, start scapulothoracic movement after week 4.	Discontinue sling, AAROM shoulder. The aim is to have full elbow and hand function, feeding and hygiene function preserved.

The specific surgical techniques of endoprosthetic reconstruction used in these patients have been previously published.[6,7] The following is a summary of the surgical techniques utilized.

Distal femur replacement

An anteromedial trans-adductor approach was performed to preserve the quadriceps muscles (and especially rectus femoris). A modular endoprosthetic system with rotating hinge knee mechanism was used to ensure proper restoration of limb length and quadriceps tension with restoration of the anatomic joint line.

Proximal tibia replacement

Reconstruction of the extensor mechanism was performed using bone graft, woven Dacron tape and rotational medial gastrocnemius muscle flap coverage. Preservation of the tibialis anterior and peroneal function was also conducted whenever possible.

Proximal femur replacement

Reconstruction of the abductor mechanism was performed using Dacron tape sutures and a cable grip system (Dall-Miles, Stryker Howmedica, Mahwah, New Jersey) to attach the remaining abductor mechanism directly to the prosthesis.

Proximal humerus replacement

Following extra-articular resection and intra-articular resection (with sacrifice of deltoid muscle and axillary nerve), dynamic and static suspension – as described by Malawer[7] – was performed to obtain shoulder stability. Gore Tex aortic graft (Gore, Newark, Delaware) was used to reconstruct the joint capsule in all intra-articular resections. Meticulous attachment of the conjoint tendon to the clavicle stump was carried out using 4mm Dacron tape in all shoulder resections. In all Tikhoff-Linberg procedures we attached the proximal humerus to the clavicle stump using a 4 mm Dacron tape.

Postoperatively, patients undergoing reconstruction around the knee were routinely placed into off-the-shelf knee immobilizers applied at the end of surgery. For surgery around the hip with reconstruction of the hip abductors, patients were placed in hip abduction pillows and then fitted with custom made abduction braces applied three to four days postoperatively. All patients were enrolled into the rehabilitation protocol immediately following surgery. All patients received inpatient and outpatient treatments ranging from two to four sessions per week in the first six weeks, then one to two sessions per week for the next six weeks. The number of sessions was adjusted according to patient progression. Patients admitted for chemotherapy, lung metastasectomy or those who experienced wound healing problems received an individualized inpatient program.

Included patients were followed prospectively and functional outcomes were routinely determined during clinical follow-up visits by means of the modified Musculoskeletal Tumor Society–International Symposium on Limb Salvage (MSTS–ISOLS) functional score; a validated objective system designed specifically for functional evaluation after limb salvage surgery.[15] This system assigned numerical values (0–5) for each of the six categories for lower extremity surgery including pain, function, emotional acceptance, gait, support, and walking. The upper extremity categories included hand positioning, dexterity, lifting ability, pain, emotional acceptance, and function. A numerical score and a percent rating are calculated to allow for comparison of results.[15] Patient scores were determined through direct patient examination and clinical interview.

Fifty-nine consecutive patients underwent limb salvage surgery at the five major anatomical locations. The mean age of the study population was 24 years (range, 5–60 years) with a mean follow-up of 24 months (range, 4–59 months). Anatomic locations included the distal femur ($n = 21$), proximal tibia ($n = 8$), proximal humerus and scapula ($n = 11$), proximal femur ($n = 6$), midshaft femur, tibia and humerus ($n = 6$), type 1 pelvic resection ($n = 3$), total femur ($n = 2$) and a combined distal femur and proximal tibia replacement ($n = 2$). Endoprostheses were used in 49 patients, biological reconstruction (bone allograft) in five patients, and no replacement

Table 6. Baseline patient data.

Variable	N
Sex	
Male	32
Female	27
Age (years)	
Mean	24
Range	5–60
Diagnosis	
Osteosarcoma	28
Chondrosarcoma	5
Ewing sarcoma	13
Metastatic disease	5
Benign aggressive tumors	5
Others	3
Reconstruction	
Endoprosthesis	49
Biological (bone graft)	5
No replacement	5
Location	
Proximal femur	6
Distal femur	21
Proximal tibia	8
Proximal humerus and shoulder girdle	11
Pelvis	3
Combined distal femur/Proximal tibia	2
Midshaft of long bone	6
Total femur	2
MSTS	
Mean	87%
Range	60–100%
Follow-up (months)	
Mean	24
Range	4–59

of the resected bone in five patients (two patients with scapulectomy requiring the Tikhoff-Linberg procedure; and three patients with type 1 pelvic resection). All surgeries were performed by the same surgeon (lead author). Table 6 shows the baseline patient data.

RESULTS

Of the included patients, 52 (88.1%) received the proposed protocol with no interruption. The seven excluded patients had a 6–10 week treatment interruption due to surgical complications or chemotherapeutic toxicity leading to physical inability to exercise.

The recorded modified MSTS–ISOLS score for all patients ranged from 60% to 100%, with a mean score of 87% (95% confidence interval (CI); 0.85–0.89). The duration of therapy ranged from four to eight months. The modified MSTS-ISOLS score was highest for patients with distal femur replacement (93%, CI; 0.91–0.95) followed by proximal tibia (88%), midshaft tibia, femur and humerus surgeries (87%), proximal femur (86%), proximal humerus and scapula (83%), pelvic resection (80%) and the two patients who underwent the Tikhoff-Linberg procedure (85%).

All patients with limb surgery achieved a plateau in their function at four to eight months after surgery, while those with pelvic resections continued to improve till 12 months after surgery. The mean MSTS score for the seven patients who had a major interruption in their protocol was 71% (95% CI; 0.64–0.82). For the three patients with complicated proximal femur replacement, two scored 70% and one scored 83% (compared to a mean score of 89% in the four patients with proximal femur replacement who received the full rehabilitation). Among the three patients with infected proximal tibia replacement, two scored 60% and one scored 86% (compared to mean score of 89% for five patients with proximal tibia who did not have interruption in the rehabilitation). The patient with type 1 pelvic resection who developed infection scored 60% (compared to a mean score of 83% of two patients with type 1 pelvic resection who received the full rehabilitation). No musculotendinous repair failure or joint instability was encountered in any of the included patients.

DISCUSSION

Although limb salvage surgery for malignant bone tumors is considered the treatment of choice, guidelines for the rehabilitation of these patients have yet to be formally established.[3,12,13] The purpose of this study is to propose detailed guidelines for this patient population stratified by anatomic location and to determine whether such guidelines would impact patient outcomes. While we acknowledge the limitations of our study including the small sample size, the lack of a homogenous control group and relatively short follow up, our results illustrate the feasibility of a formalized rehabilitation protocol for limb salvage surgery and demonstrates the potential benefit of such a protocol with regards to patient function.

An exhaustive search of the relevant literature did not reveal any previously published physical therapy protocols for patients undergoing limb salvage surgery for bone tumors despite the fact that limb-sparing surgery has been performed over the last 40 years. Only sporadic guidelines have previously been reported.[7] The advantage and strength of a well-documented protocol lies in its practicality, applicability and reproducibility. Rigid protocols provide detailed description of the required exercises and a very clear

Table 7. Literature review of functional score after limb salvage surgery.

Name of series	No. of patients	Mean follow up (years)	Mean modified MSTS/ISOLS score (%)
Gosheger et al. [7]	250	3.8	83
Ahlmann et al. [1]	211	3.1	74
Shin et al. [17]	208	12	63
Gitelis et al.$^{PT, DF}$ [6]	80	5.3	80
Kabukcuoglu et al.^{PF} [13]	54	9	83
Kawai et al.^{DF} [14]	40	8^{m}	80
This Study	59	2	87

PF: proximal femur; DF: distal femur; PT: proximal tibia; m: median value was reported.

timeframe for the conduct of each stage of rehabilitation. This is especially true for the proper coordination of patients who are required to receive rehabilitation by therapists who are not familiar with limb salvage surgery and can be beneficial for international patients who will continue their rehabilitation in their home country.

Our results suggest that adherence to a strict, properly documented, and anatomically appropriate rehabilitation program can improve the functional outcome of patients after limb-sparing surgery. While previous studies have reported functional outcomes for endoprosthetic reconstruction following limb-sparing surgery (Table 7), none have devised any standardized approach to patient rehabilitation.

Nonetheless, it should be noted that no matter how extensive and detailed rehabilitation is, it is not a substitute for muscular tissue and tendinous attachment preservation. While oncologic principles frequently dictate sacrifice of healthy tissues, appropriate surgical techniques to restore function, as guided by well-documented approaches remain critical in maximizing functional outcomes.[7]

The good functional outcome reported in our study is likely due to both improved surgical techniques and a team approach using standardized guidelines for the rehabilitation of patients. In our experience, we observed that lack of compliance in some patients was mainly related to chemotherapy-induced fatigue and/or a general deconditioning of these patients. Additional challenges were encountered in patients admitted for other surgeries (e.g. lung metastasectomy) and following surgical complications.

CONCLUSIONS

Based on this initial pilot study, we believe that developing a standardized rehabilitation protocol is feasible, and can improve functional outcome as it provides a standardized road map for the therapist to follow. The devised protocols are easy to implement and adapt to the patient's individual needs. Widespread implementation of standardized guidelines may significantly improve postoperative management of these patients.

CONFLICT OF INTEREST

None.

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